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Three-dimensional changes in the position of unopposed molars in adults

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SUMMARY The aim of this study was to longitudinally examine, in adults, changes of position in the three dimensions of maxillary molars unopposed for more than 10 years. Twelve healthy mature adults (six males, six females; mean age 45 years 11 months) with unopposed molars were followed-up for a mean period of 10 years 7 months. Plaster casts were made at the first and last examination. The patients presented 22 unopposed maxillary molars at both recordings and 14 posterior teeth with antagonists, at least one in each subject, without significant modifications during the study period. On three-dimensional scanned plaster casts, changes in the centroid of the occlusal surface were measured in the three dimensions. The changes observed on both occasions were compared with a *t*-test.

Vertical displacement of unopposed molars [0.8 mm, standard deviation (SD) 0.65 mm] and controls (0.4 mm, SD 0.2 mm) was noted. The unopposed teeth overerupted more than the controls ($P \leq 0.06$); periodontally affected molars erupted more than periodontally healthy molars ($P \leq 0.01$). There was significant mesial displacement of unopposed molars without mesially adjacent teeth when compared with their respective controls ($P \leq 0.04$). Palatal movement was observed in the unopposed teeth (0.9 mm, SD 0.6 mm) and was significantly greater than that in the controls (0.5 mm, SD 0.3 mm; $P \leq 0.02$).

There is displacement of unopposed teeth in the three dimensions in the long term, although this is clinically insignificant in periodontally healthy adults. The observed changes are either the result of late growth remodelling or a consequence of altered dental equilibrium following antagonist tooth loss.

Introduction

A common belief among dentists is that permanent teeth that remain unopposed long term tend to migrate, creating considerable clinical problems (Lyka *et al.*, 2001). In a recent clinical investigation on molars without antagonists, 83 per cent of teeth displayed overeruption ranging from 0.5 to 5.4 mm (Craddock and Youngson, 2004). However, in that study no information was given regarding either the length of the period the teeth remained unopposed or the age of the patients when the teeth were extracted.

Age seems to be an important factor for the vertical migration of unopposed molars. Thus, in children the maxillary first primary molars without antagonist, if not ankylosed, overerupt towards the extraction space (Yonezu and Machida, 1997). Furthermore, Smith (1996) observed that in children and adolescents who had extraction of upper second molars for orthodontic reasons, the unopposed lower second permanent molars showed a marked overeruption 10 years later.

Similar changes as those observed in young individuals have been found in adults but to a lesser extent (Love and Adams, 1971; Kiliaridis *et al.*, 2000). In adults, the position of unopposed molars showed less extensive supraposition, nevertheless after a long observation period of at least 10 years; 25 per cent of the documented molars showed overeruption of 2 mm or more. Besides this vertical displacement, other movements such as tipping and rotation occurred.

The present available data are based on case reports or cross-sectional studies that include little information concerning the subjects, their age when the teeth were extracted or the time period that the teeth remained unopposed.

There appears to be no longitudinal study monitoring changes in the position (vertical displacement, disto-mesial, bucco-palatal) of molars without antagonists. The aim of the present investigation was to examine, in adults, the changes of position in the three dimensions of maxillary molars that had been unopposed for a period of more than 10 years.

Subjects

Thirteen adults (six males, seven females; mean age 45 years 11 months, range 25–69 years) with unopposed molars were followed-up for at least 10 years [mean follow-up period 10 years 7 months, standard deviation (SD) 16 months] in the dental clinic of the University of Gothenburg, Sweden. The 13 subjects presented, in total, 24 unopposed maxillary molars at both recordings. Seventeen posterior teeth with antagonists, at least one for each subject, served as the controls. One female patient with an unopposed molar and two control teeth, along with one unopposed molar and a control tooth from the rest of the group were excluded due to extensive restorations that were replaced, during the period of the study. That reduced the group to 12 adults (six males, six females; mean age 45 years 11 months, range 25–69 years) with 22 unopposed molars and 14 control teeth without any significant modifications of their morphology during the observation period.

The patients reported no systemic diseases. For each subject, two sets of casts were fabricated: one a short period after the extraction of the mandibular antagonist tooth and a second set at a follow-up examination 10 years later. On both occasions, alginate impressions were taken and were poured with type IV gypsum for dental casts.

Methods

All casts were scanned with a three-dimensional (3D) single slit, one sense laser scanner (Laserscan 3D, Willytec GmbH, Gräfelfing, Germany). The cast was placed on a base and a Gaussian pattern, monochromatic, slit laser beam emitted from a source point projected onto its surface. The base is articulated, mobile, and can move on both the x- and y-axis. The models were placed on the articulated base with their occlusal plane (as defined by all posterior teeth excluding the unopposed tooth) parallel to the ground.

On the 3D model, the position of the unopposed molar and that of the control tooth, as seen on the initial and final casts, were compared. For both teeth, the middle of the distance between the mesial, distal, vestibular, and lingual marginal crests were used as reference points. All points were localized on reproducible areas of each tooth that were not exposed to abrasion and were similar on both sets of casts. The point of intersection of the bimedians joining the midpoints of the opposite sides was the centroid of the occlusal surface (Figure 1).

The changes between the two 3D models on the Cartesian co-ordinate system (x, y, z) were measured with 3D imaging software (Match3D, Willytec GmbH). Disto-mesial tooth displacement and bucco-lingual movement were assessed on the x- and y-axis, respectively, and eruption was measured on the z-axis. Movement towards the mesial, lingual, and overeruption were marked as positive values. The changes observed for the four reference points were averaged for each axis so that they would correspond to the representation of the movements of the centroid of each tooth's occlusal surface.

Statistical analysis

The measurements for normal distribution were tested with a Shapiro–Wilk test, and an independent sample t-test was used to compare the means of all measurements. Significance was set at 0.05. An unpaired t-test was used to compare the means and to assess differences between groups at the 95 per cent confidence interval. To limit the influence of interindividual variability of the measurements for each tooth in patients with more than one unopposed molar or control tooth, the mean of the values were used and compared with a paired t-test.

Figure 1 Points of reference used on the initial and final study models. 1. Middle of the mesial marginal crest, 2. middle of vestibular marginal crest, 3. middle of distal marginal crest, 4. middle of lingual marginal crest, 5. centroid of the occlusal surface. For each tooth under study, there was a comparison in the position of the reference points in the three dimensions between the initial and final recording. The structure of reference was the palatal vault, distal of the third rugae. The positions of the points of reference were compared as they appeared in the initial and final casts.

Pearson's correlation analysis was used between the z values for the buccal point of reference and the difference between the vertical measurements for buccal and palatal references, allowing the pattern of the observed vertical displacement to be determined.

To evaluate the importance of adjacent teeth in the disto-mesial movement observed in both groups, a linear regression model was used. The amount of disto-mesial displacement was the dependent variable and the independent value was the existence or not of the adjacent tooth mesially. The same test was performed with the independent variable, the existence or not of distally adjacent teeth.

Statistical evaluation was undertaken with the Statistical Package for Social Sciences, version 13.0 (SPSS Inc., Chicago, Illinois, USA).

Error of method

The replication of measurements is important in the control of random errors (Houston, 1983). To assess the magnitude of random errors, the potential sources were identified: the error of the scanner and the error of the operator during localization of references (operator error). The scanner was pre-calibrated and for relatively large objects (such as dental casts), according to the technical data provided by the manufacturer, the accuracy after 3D matching is 8.5 μm and the reproducibility 2 μm. One author (PC) carried out the double localization of the same points of reference with an interval of 10 weeks between the two measurements. The differences in the co-ordinates in the Cartesian system were assessed and compared using a paired sample t-test. A high repeatability of the localization of the reference points (P = 0.192) and a high correlation between the two sets of

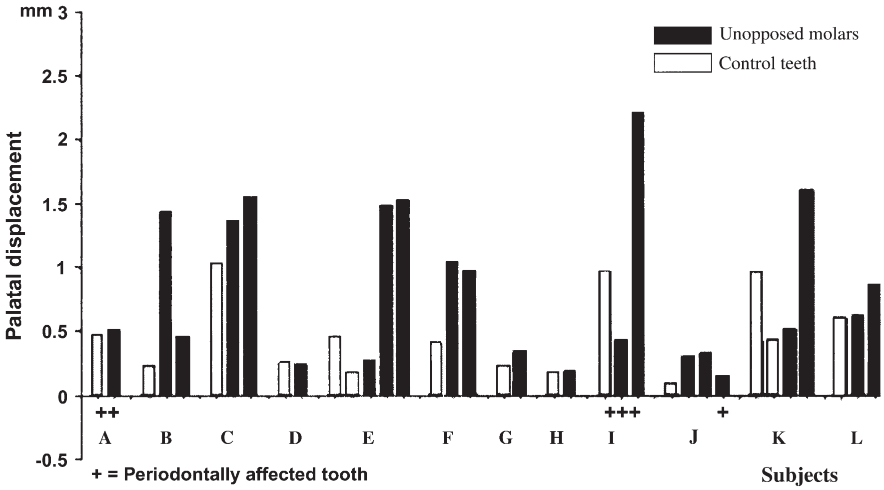

Figure 2 Vertical movement of the centroid. All the molars (unopposed and controls) showed signs of eruption (positive values indicate eruption, + indicates periodontally affected tooth). There was greater vertical displacement in periodontally affected unopposed molars.

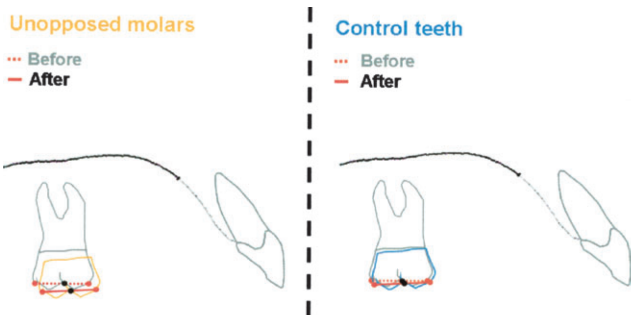

Figure 3 Diagrams showing vertical displacement of posterior teeth, unopposed molars, and their controls.

measurements ($r = 0.6$) were found. The standard error was calculated using Dahlberg's (1940) formula for each of the three axes separately and was found to be low: for the *x*- and *y*-axis it was 7.8 and 8.6 μm, respectively, and for the *z*-axis 17.1 μm. The cumulative error in the localization of the centroid of the occlusal plane was 16.3 μm.

Results

The centroid of the occlusal plane showed signs of eruption of most teeth, the 22 unopposed molars (0.80 mm, SD 0.65 mm) and the controls (0.40 mm, SD 0.20 mm). Periodontally affected unopposed molars erupted more (1.97 mm, SD 0.58 mm) than periodontally healthy teeth (0.48 mm, SD 0.17 mm; $P \leq 0.01$). Comparing the vertical displacement observed in periodontally healthy unopposed molars with the respective controls, no significant difference was found in vertical displacement during the study period (Figures 2 and 3). The rate of vertical displacement was similar for periodontally healthy unopposed molars (0.05 mm/year) and controls (0.04 mm/year).

For unopposed molars, although the displacement of the palatal reference was smaller than the buccal, there was a higher correlation between the eruption of the vestibular side of the molar and the difference in vertical displacement of the palatal and vestibular reference ($P = 0.03$; Figures 4 and 5). This indicates greater eruption of the vestibular side of the molar and a simultaneous rotation of the molar in the transverse plane to the palatal direction.

All teeth, moved mesially. No significant differences were observed ($P = 0.08$) when the two groups were compared for disto-mesial movement of the teeth (Table 1, Figure 6). On the contrary, significant differences ($P = 0.04$) were found when the disto-mesial displacement of unopposed molars, with and without mesially adjacent teeth were compared, and also when multiple observations between unopposed molars and controls were compared with a *t*-test ($P = 0.03$; Table 2). The linear regression model for unopposed molars and control teeth showed a high significance when a mesially adjacent tooth was present ($P = 0.01$; Figure 7).

There was palatal movement of the centroid of the occlusal surface for both groups (Table 1). For the unopposed teeth (0.9 mm, SD 0.6 mm), this was significantly greater than for the controls (0.5 mm, SD 0.3 mm; $P = 0.02$).

Discussion

In this study, the displacement of the centroid of the occlusal plane was observed in the three dimensions. Over-eruption was found both for unopposed molars and for teeth with antagonists. For periodontally healthy unopposed molars, although this change was statistically significant, it was not clinically significant. This is in agreement with previous findings (Love and Adams, 1971; Shugars *et al.*, 2000) that also showed severe over-eruption in individuals who had teeth

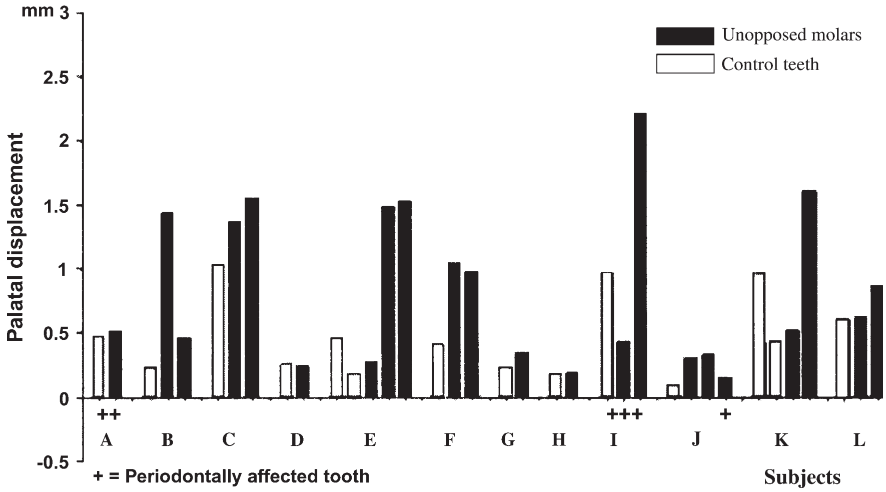

Figure 4 Bucco-lingual movement of the centroid. The displacement for unopposed teeth was significantly greater ($P = 0.02$) than that of the controls (positive values indicate palatal displacement; + indicates periodontally affected tooth).

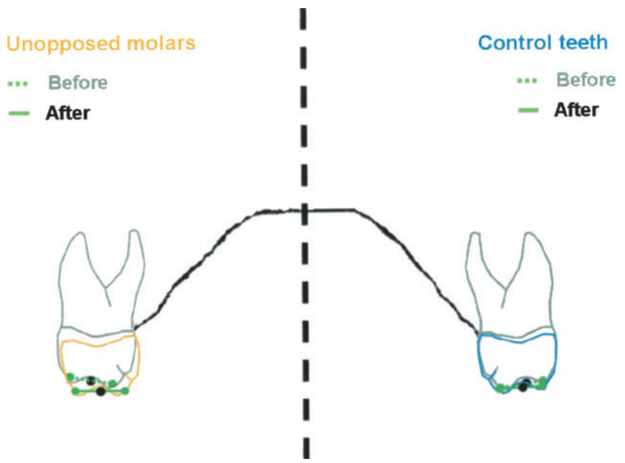

Figure 5 Diagrams showing the mean displacement of the posterior teeth, unopposed molars, and their controls, in the transverse plane.

extracted at a young age which remained unopposed during the period of craniofacial growth (Smith, 1996), or when the teeth had less periodontal support (Compagnon and Woda, 1991).

Another important finding was that teeth with antagonists showed changes in relation to their initial position. The latter is not a methodological error but it is in line with the results of studies on late growth. In the subjects in the present study, the major part of maxillary growth was complete (Sarnäs and Solow, 1980; Tallgren and Solow, 1991) and only late growth changes such as continuous tooth eruption can be observed (Forsberg *et al.*, 1991). This can be attributed to the continuous activity of the periodontal ligament and maxillary bone activity which is mainly related to bone remodelling and minor periosteal activity (Forsberg *et al.*, 1991).

Another indication for the changes in the vertical dimension is found in implant research. Long-term studies on anterior teeth adjacent to implants showed that each single teeth moved occlusally at a recorded average rate of 0.1 mm/year (Thilander *et al.*, 1994, 2001; Bernard *et al.*, 2004). These studies concerned teeth in the anterior region that have less occlusal opposition than posterior teeth in occlusion. According to these findings, molars without antagonists in adults and thus with less occlusal opposition, can overerupt on average 1 mm in a period of 10 years, resulting in a slight overeruption which is probably not of any clinical significance. However, the amount of continuous eruption varies from one individual to another; on certain occasions, not all teeth reach occlusal contact, as seen in dental open bite cases.

Periodontal conditions have also been reported to be a factor associated with overeruption. In this study, when considering overeruption, the periodontally affected unopposed molars, during a 10-year period, presented a pronounced vertical displacement on average 1.97 mm when compared with periodontally healthy teeth (average 0.48 mm). The patients with periodontally involved teeth showed signs of generalized periodontal disease but which seemed to contribute to displacement of the control tooth in only one subject. The number in this subgroup was small, and eliminated annualization of the post-eruptive displacement of the periodontally affected teeth was not carried out. Besides, it would be expected for healthy teeth to show possibly uniform vertical displacement over time due to continuous activity of the periodontal ligament (Ten Cate and Nanci, 2003), but for periodontally affected teeth, due to the nature of the disease, uneven vertical movement during the period of observation is very probable. These findings are in line with previous studies that found that the periodontal condition is a factor associated with vertical displacement (Compagnon and Woda, 1991). A possible explanation could be that the loss of coronal periodontal attachment can facilitate the eruption potential of the tooth

Table 1 Independent samples test. Comparison of the displacement of the centroid in the three dimensions (mm).

	Control teeth (n = 14)		Unopposed molars (n = 22)		P	95% CI	
	Mean	SD	Mean	SD		Lower	Upper
Eruption	0.4	0.2	0.8	0.65	0.06	−0.75	0.15
Disto-mesial	0.35	0.2	0.6	0.55	0.08	−0.6	0.4
Bucco-palatal	0.5	0.3	0.9	0.6	0.02*	−0.7	–0.1

SD, standard deviation; CI, confidence interval
*$P < 0.05$.

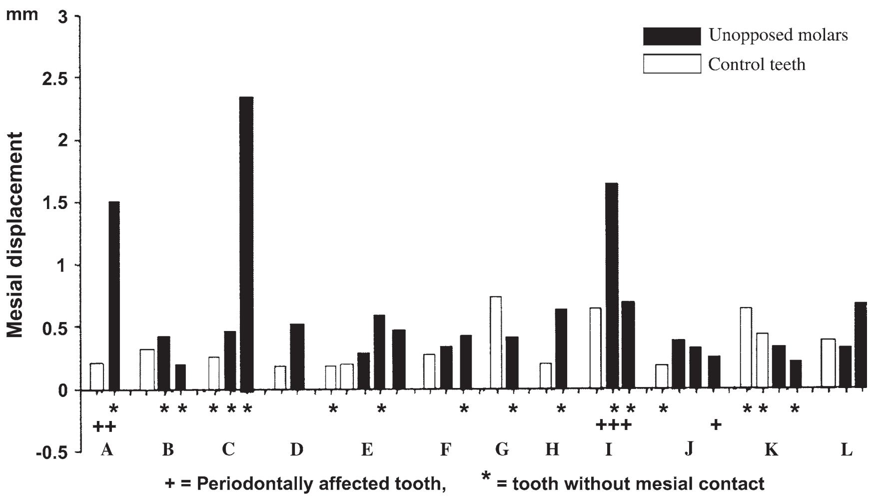

Figure 6 Movement of the centroid of the occlusal surface in the occlusal plane. All teeth moved mesially, the unopposed tooth moved more (median 0.44 mm, range 0.21–2.37 mm) than controls (median 0.30 mm, range 0.19–0.73 mm; $P = 0.05$). Positive values indicate mesial displacement. * indicates tooth without mesial contact, + indicates periodontally affected tooth.

Table 2 Tooth displacement observed in the 12 subjects. When more than one unopposed molar or control tooth was present, the mean displacement per individual was used (comparison with paired t-test).

	Control teeth		Unopposed molars		P	95% CI	
	Mean	SD	Mean	SD		Lower	Upper
Eruption	0.4	0.3	0.8	0.65	0.03*	0.05	0.7
Disto-mesial	0.35	0.2	0.6	0.55	0.03*	0.03	0.55
Bucco-palatal	0.6	0.45	0.85	0.6	0.06	−0.01	0.5

SD, standard deviation; CI, confidence interval.
*$P < 0.05$.

without the necessity of vertical displacement of the whole alveolar process that could impede eruptive movement of this tooth. However, the correlation between moderate or severe overeruption and periodontal disease requires further investigation.

A significant mesial displacement of unopposed molars without mesially adjacent teeth was also observed. This displacement was independent of the presence or otherwise of distally adjacent teeth. When observed on control teeth, it may be due to the mesial vector of the occlusal forces and can be considered one of the reasons for the development of late crowding in adults. These findings are in agreement with Kiliaridis *et al.* (2000) where excessive tipping of unopposed molars without adjacent teeth was noted in a similar sample.

Another important finding was the significant displacement of all teeth palatally, predominantly of the unopposed molars. This can be attributed to the continuous force of the soft tissues adjacent to the tooth and the perioral

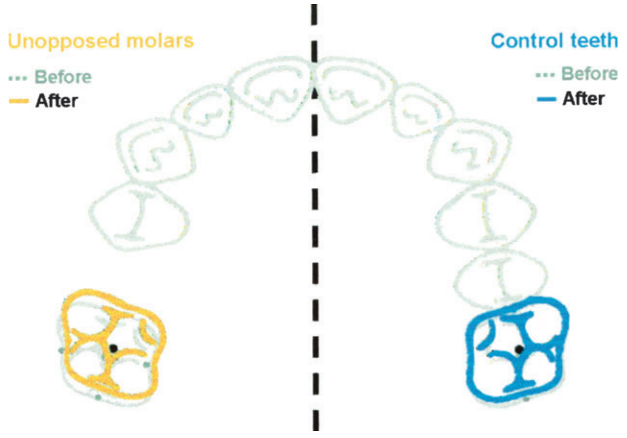

Figure 7 Diagrams showing disto-mesial displacement of the posterior teeth, unopposed molars, and their controls.

musculature, predominantly the buccinator muscle, which is an important environmental determinant of tooth position (Proffit, 1978). Its constant and apparently light force is compensated in the control teeth by occlusal interferences provided by the antagonists that are not present on the unopposed side. Another factor for compensation of the control teeth can be occlusal forces; they play an important role in maintaining the transverse dimension of the dental arches (Kiliaridis *et al.*, 2003), but there are no occlusal forces on teeth without antagonists.

The assumption that the tongue takes the place of antagonist teeth once they are extracted could not be confirmed. The role of the tongue and the movements that can be partially attributed to its position can only be speculated. An assumption is that the tongue impedes vertical displacement of the palatal cusps, but in the transversal plane it can provide a stabilizing force opposing the light but continuous force of the cheeks (Proffit, 2000).

The method used in the present study permitted assessment of movements of unopposed molars and control teeth in the three dimensions, in relation to structures close to the region of interest.

Ideally, the individuals investigated should have been followed annually. Nevertheless, this longitudinal study was based on two recordings at least 10 years apart. This excludes information concerning the possible events in the periodontal status of teeth during this period. Only their present condition during the examination session was assessed. Thus, vital data on these teeth are lacking but limited numbers of periodontally affected teeth could be observed due to loss of attachment and increase of clinical crown length. This was not the case for the vast majority of teeth examined.

Besides the measurement error, there is a potential error in casting models (impression and settling of casts). The presented values include this potential error; however, this error influenced both groups of teeth equally. Besides the potential error of the casts (Duke *et al.*, 2000), the changes observed were towards only one direction on each axis revealing small contributions of the setting error.

Another possible source of error could be the localization of the reference points. To diminish this, the points of reference on surfaces were localized on 3D images that had no restorations or were not exposed to abrasion during the period of the study.

There was also a variation in the type of teeth studied; the 'experimental teeth' were unopposed molars, while the control teeth were posterior teeth (molars and premolars). Ideally matched controls should have been used, but this was realistically not possible; therefore, premolars were also included as control teeth. Although their number was small, comparison of these two groups showed no statistically significant difference in the displacement pattern.

A limitation of the study is the small number of periodontally affected teeth (n = 4). The findings can be considered as an indication of what occurs in periodontally affected unopposed molars. Further studies are necessary to confirm the findings for these teeth.

This study provides evidence of displacement of teeth in the three dimensions in the long term. The change in the position of unopposed molars in periodontally healthy adult individuals is clinically insignificant. The small changes observed are either a result of late growth changes during adulthood, or a consequence of altered dental equilibrium following the loss of an antagonist tooth.

Conclusions

1. There is a change in the position of all teeth in the three dimensions.
2. Molars with periodontitis are more prone to overeruption than those with a healthy periodontium.
3. There is significant mesial displacement of unopposed molars with no mesially adjacent teeth.
4. There is a palatal displacement of all teeth, predominantly of unopposed molars.

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References

Bernard J P, Schatz J P, Christou P, Belser U, Kiliaridis S 2004 Long-term vertical changes of the anterior maxillary teeth adjacent to single implants in young and mature adults. A retrospective study. Journal of Clinical Periodontology 31: 1024–1028

Compagnon D, Woda A 1991 Supraeruption of the unopposed maxillary first molar. Journal of Prosthetic Dentistry 66: 29–34

Craddock H L, Youngson C C 2004 A study of the incidence of overeruption and occlusal interferences in unopposed posterior teeth. British Dental Journal 196: 341–348

Dahlberg E 1940 Statistical methods for medical and biological students. Interscience Publications, New York

Duke P, Moore B K, Haug H P, Andres C J 2000 Study of the physical properties of type IV gypsum, resin-containing, and epoxy die materials. Journal of Prosthetic Dentistry 83: 466–473

Forsberg C M, Eliasson S, Westergren H 1991 Face height and tooth eruption in adults—a 20-year follow-up investigation. European Journal of Orthodontics 13: 249–254

Houston W J B 1983 The analysis of errors in orthodontic measurements. American Journal of Orthodontics 83: 382–390

Kiliaridis S, Georgiakaki I, Katsaros C 2003 Masseter muscle thickness and maxillary dental arch width. European Journal of Orthodontics 25: 259–263

Kiliaridis S, Lyka I, Friede H, Carlsson G E, Ahlqwist M 2000 Vertical position, rotation, and tipping of molars without antagonists. International Journal of Prosthodontics 13: 480–486

Love W D, Adams R L 1971 Tooth movement into edentulous areas. Journal of Prosthetic Dentistry 25: 271–278

Lyka I, Carlsson G E, Wedel A, Kiliaridis S 2001 Dentists' perception of risks for molars without antagonists. A questionnaire study of dentists in Sweden. Swedish Dental Journal 25: 67–73

Proffit W R 1978 Equilibrium theory revisited: factors influencing position of the teeth. Angle Orthodontist 48: 175–186

Proffit W R (ed.) 2000 The etiology of orthodontic problems. In: Contemporary orthodontics. Mosby, St Louis, pp. 113–144

Sarnäs K-V, Solow B 1980 Early adult changes in the skeletal and softtissue profile. European Journal of Orthodontics 2: 2–12

Shugars D A, Bader J D, Phillips Jr S W, White B A, Brantley C F 2000 The consequences of not replacing a missing posterior tooth. Journal of the American Dental Association 131: 1317–1323

Smith R 1996 The effects of extracting upper second permanent molars on lower second permanent molar position. British Journal of Orthodontics 23: 109–114

Tallgren A, Solow B 1991 Age differences in adult dentoalveolar heights. European Journal of Orthodontics 13: 149–156

Ten Cate A R, Nanci A 2003 Physiologic tooth movement: eruption and shedding. In: Ten Cate A R (ed.) Ten Cate's oral histology: development, structure and function Mosby, St Louis, pp. 275–298

Thilander B, Ödman J, Gröndahl K, Friberg B 1994 Osseointegrated implants in adolescents. An alternative in replacing missing teeth?. European Journal of Orthodontics 16: 84–95

Thilander B, Ödman J, Lekholm U 2001 Orthodontic aspects of the use of oral implants in adolescents: a 10-year follow-up study. European Journal of Orthodontics 23: 715–731

Yonezu T, Machida Y 1997 Occlusal migration of the maxillary first primary molars subsequent to the loss of antagonists. Bulletin of Tokyo Dental College 38: 201–206